Evaluation of the Potential for Using Dry Rather Than Semi-moist Food for Culturing Coho Salmon in British Columbia Hatchery Facilities 1. Quinsam Hatchery 1976 Brood

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EVALUATION OF THE POTENTIAL FOR USING DRY RATHER THAN SEMI-MOIST FOOD FOR CULTURING COHO SALMON IN BRITISH COLUMBIA HATCHERY FACILITIES

1. QUINSAM HATCHERY 1976 BROOD

by

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ABSTRACT

Markert, J. R., D. A. Higgs, D. MacQuarrie, J. R. McBride, B. S. Dosanjh, J. Van Tine, and R. Reinhardt. 1985. Evaluation of the potential for using dry rather than semi-moist foods for culturing coho salmon in British Columbia Hatchery Facilities. 1. Quinsam Hatchery 1976 brood. Can. Tech. Rep. Fish. Aquat. Sci. No. 1385: 30 p.

This is the first of a series of studies undertaken to investigate the possibility of using dry diets (<10% moisture) rather than the standard Oregon Moist Pellet diet (OMP ~30% moisture) for juvenile coho smolt production in B.C. hatcheries. Juvenile coho of approximately 2.8 g initial mean weight were fed two West Vancouver Laboratory dry diets (W.V. 1, W.V. 2) the Abernathy dry diet or OMP for 310 days. The W.V. diets had 25 (W.V. 1) or 50 (W.V. 2) percent of the fish meal protein replaced with an equivalent level of protein from a mixture of poultry-by-product meal and feather meal. All diets had similar protein and estimated metabolizable energy contents. Ration level was adjusted to either 80 (W.V. 1, W.V. 2, Abernathy, and OMP) or 65 (OMP) percent of the OMP feeding schedule and in the former case all groups were maintained on equivalent caloric intake /g wet body weight.

The seasonal growth pattern was the same for all groups and was characterized by rapid growth in summer and early fall, slow growth in late fall and winter, and resumed rapid growth after the winter solstice until release in early May. Food and protein utilization showed the same seasonal trend as that mentioned for growth. At the time of release a significant size difference developed (OMP 80 > Abernathy > W.V. 1 > W.V. 2 > OMP 65) because of ration level and diet composition. Observed mortality was negligible in most groups whereas the unaccountable mortality was highly variable. The histological structure of several selected organs and tissues was normal in all groups. However, the W.V. groups had a higher incidence of bacterial kidney disease than those fed the commercial diets. All groups were able to osmoregulate satisfactorily before release in seawater.

Percent returns for the W.V. groups were better than those of production fish (OMP 65) but poorer than those previously fed Abernathy or OMP at the 80% level.

It is concluded that there is good potential for employing dry diets for smolt production provided that the type, level and quality of dietary components and the manufacturing process are carefully controlled.

Key words: diets, dry, moist, coho, Oncorhychus kisutch, survival, growth, protein source

RÉSUMÉ

Markert, J. R., D. A. Haggs, D. MacQuarrie, J. R. McBride, B. S. Dosanjh, J. Van Tine, and R. Reinhardt. 1985. Evaluation of the potential for using dry rather than semi-moist foods for culturing coho salmon in British Columbia Hatchery Facilities. 1. Quinsam Hatchery 1976 brood. Can. Tech. Rep. Fish. Aquat. Sci. 1385: 30 p.

Il s'agit de la première d'une série d'études entreprises afin d'étudier la possibilité d'utiliser des diètes sèches (< 10% d'humidité) plutôt que la diète régulière constituée de boulettes humides Oregon (BHO~30% d'humidité) pour produire de jeunes saumons cohos dans les piscifactures de la C.-B. On a donné à de jeunes saumons cohos dont le poids moyen initial était d'environ 2,8 g deux diètes sèches préparées par le Laboratoire de Vancouver Ouest (V.O. 1, V.O. 2), la diète sèche d'Abernathy ou des BHO pendant 310 jours. Dans les diètes de V.O., 25% (V.O. 1) ou 50% (V.O. 2) des protéines à base de farine de poisson ont été remplacées par un équivalent protéinique provenant d'un mélange de farine de sous-produits de volaille et de farine de plumes. Toutes les diètes avaient un contenu protéinique et un contenu estimatif en énergie métabolisable similaires. Le niveau de la ration a été ajusté à 80% (V.O. 1, V.O. 2, Abernathy, et BHO) ou à 65 % (BHO) du programme d'alimentation pour les BHO et, dans le premier cas, la consommation de calories/g de poids humide corporel a ét maintenue équivalente pour tous les groupes.

Le rythme de croissance saisonnier était le même pour tous les groupes et était caractérisé par une croissance rapide l'été et au début de l'automne, par une croissance lente à la fin de l'automne et l'hiver, et une reprise de croissance rapide après le solstice d'hiver, jusqu'à la remise à l'eau au début de mai. L'utilisation de la nourriture et des protéines a donné lieu à la même tendance saisonnière que celle mentionnée pour la croissance. Au moment de la remise à l'eau, il y avait une différence de taille importante (BHO 80 > Abernathy > V.O. 1 > V.O. 2 > BHO 65) à cause de la quantité de la ration et de la composition des diètes. La mortalité observée a été négligeable dans la plupart des groupes tandis que la mortalité inexplicable était très variable. La structure histologique de plusieurs organes et tissus choisis était normale pour tous les groupes. Cependant, les cas de maladie bactérienne du rein étaient plus nombreux chez les groupes nourris avec les diètes de V. O. que chez ceux alimentés avec les diètes commerciales. La régulation osmotique s'est faite de façon satisfaisante chez tous les groupes avant qu'on les libère dans l'eau salée.

Les retours en pourcentage ont été plus élevés chez les groups de V.O. que chez ceux des poissons de production (BHO 65), mais plus faibles que chez ceux à qui on avait donné la diète d'Abernathy ou de BHO au niveau de 80%.

On conclut que l'emploi de diètes sèches pour la production de saumoneaux est très prometteur pourvu que le type, la quantité et la qualité des éléments de la diète de même que le processus de fabrication soient soigneusement contrôlés.

Mots-clés: diètes, sec, humide, saumon coho, Oncorhychus kisutch, survie, croissance, source de protéines

INTRODUCTION

This is the first of a series of studies to investigate the possibility of using dry diets (< 10 % moisture) rather than the Oregon moist pellet diet (OMP; 30 % moisture) for culturing coho salmon in B.C. hatchery facilities. Successful implementation of dry diets for coho salmon culture will reduce hatchery food costs which presently account for 25 to 40% of the operating budget. This is because dry diets are less expensive to manufacture, transport and store than moist diets. In this study an attempt was made to reduce hatchery food costs further by decreasing reliance on expensive fish meal to furnish most of dietary protein needs. Thus in the test dry diets we replaced 25 or 50% of the protein provided by fish meal with protein from a mixture of poultry-by-product meal and feather meal. Previous laboratory findings (Higgs et al. 1979) suggested that this approach would be successful but this required confirmation on a production scale.

MATERIALS AND METHODS

On June 1, 1977 approximately 50,000 coho fry (X weight = 2.81 g), the progeny of the 1976 Quinsam River coho broodstock, were placed in each of four Burrows ponds (24.6 m x 5.6 m x 3.0 m). These ponds were supplied with 400 - 600 gpm of aerated ground water which ranged in temperature from 8 - 11°C.

The fish in each pond were fed Oregon Moist Pellets (OMP; Table 1) in accordance with the OMP feeding schedule. However, on June 28, 1977 each group was assigned one of four dietary treatments. One group continued to receive OMP whereas the other groups were fed either the Abernathy salmon diet (Table 1A), West Van #1 (W.V. #1; Table 2) or West Van #2 (W.V. #2; Table 2). The prescribed ration level for each of the foregoing groups was 80% of the OMP feeding schedule on a gross caloric basis. All diets contained similar levels of protein and metabolizable energy (Table 3). Conversion from OMP to the respective dry diets was accomplished in three successive 3-day intervals as follows; 3/4 OMP: 1/4 dry diet (D), 1/2 OMP: 1/2 D, 1/4 OMP: 3/4 D. All diets were dispensed by automatic feeders every 20 minutes from dawn to dusk. Table 4 shows estimates of the actual rations consumed by the groups during the study.

Both W.V.1 and W.V.2 were prepared in the pilot feed plant at the West Vancouver laboratory until December 9, 1977 at which time the amount of feed exceeded the capacity of these facilities. A contract with a local poultry feed manufacturer was established and thereafter W.V.1 and W.V.2 were manufactured at their facilities at approximately twelve week intervals.

SAMPLING PROCEDURES

The fish in the four ponds were sampled approximately every 28 days (Appendix table 1). On August 23, 1977, day 56 of the experiment, a fifth group was included in the sampling schedule. This was comprised of 80,000 coho fry from the same stock as that in the four experimental ponds. This production group was fed OMP at 65% of the OMP feeding schedule on a gross caloric basis which is the standard level of dietary intake for production coho at this hatchery. Preliminary studies by Bilton et al. (1982) indicated that such a ration level at this hatchery would result in fish of the correct size at release to give highest ocean survival.

The sampling of each group entailed crowding the fish into a small area of the pond using a pole seine and a divider screen. Three large random samples of fish were taken with a dip net and each was placed into a separate container. The fish in each of these three containers were sub-sampled and placed into a fourth container. Lastly, a total of 150 fish were withdrawn randomly from the fourth container and individual weights and lengths of anesthetized (2-phenoxyethanol; 0.5 m/1) fish were recorded.

Ten fish were sampled from each of the four experimental groups every two months for assessment of fish health and several times during the study for evaluation of the histological structure of selected organs using previously described procedures (Higgs et al. 1979). Moreover, on day 310 additional samples of ten fish were taken from each group for whole body proximate analysis according to the methods of Higgs et al. (1979). Diets were analyzed after each batch of food was manufactured using the same procedures.

The osmoregulatory ability of each group was assessed prior to ocean release by the method of Clarke and Blackburn (1977).

To obtain estimates of the effect of dietary treatment on ocean survival, approximately 25,000 fish from each of the four groups were marked by removing the adipose fin and then differentially tagged according to the procedure of Jefferts et al. (1963). Approximately 14% of the production group or 48,000 fish were also marked in a similar manner. All marking and tagging were done in November 1977. The production fish were released into the Quinsam River on the evenings of May 1-4, 1978, and the fish fed the test diets were released on the evening of May 7, 1978.

DATA ANALYSIS

A semilogarithmic plot of geometric means for wet weights of the groups revealed three natural growth stanzas or periods of exponential growth (Fig. 1). Stanza I extended from day 0 to 84, stanza II from day 85 to 225, and stanza III from day 226 to 310. Mean wet weights, lengths and condition factors (Vanstone and Markert 1968) for each sample time are given in Appendix table 1. However, for clarity values are given on most tables for the beginning and end of each stanza.

Specific growth rates (Brett 1979), food conversion (wet weight gain (g) ÷ dry food intake (g)), food conversion efficiency (dry weight gain (g) x 100 ÷ dry food intake (g)), protein efficiency ratio (wet or dry weight gain (g) ÷ protein intake (g)) and protein utilization (protein gain (g) x 100 ÷ protein intake (g)) were computed for each stanza (Figs. 3, 4).

The data were subjected to various types of Analyses of Variance (ANOVA, see individual tables) and when appropriate to Newman Keuls test or Scheffes test (growth rates only) with $P = 0.05$ to detect significant differences between treatment means. The standard error of the mean (SEM) was derived by using the appropriate error mean square from the ANOVA as the estimate of sample variance.

RESULTS AND DISCUSSION

Differences between diets in composition and ingredient quality influenced the growth rates of the fish in stanzas I and II (Tables 5, 6, Fig. 1). Significant differences in weight were noted at the end of each stanza. Our data also suggest that manufacturing techniques influenced food quality. For example, when W.V. #1 and W.V. #2 were manufactured in the laboratory pilot plant, excellent growth was observed (Stanza I, Tables 5, 6, Fig. 1). However, significant reduction in growth resulted when these diets were commercially manufactured according to the same specifications. Hence the fish fed OMP at the 80% level were significantly larger than those fed OMP at 65% level, W.V. #1 and W.V. #2 by the end of the experiment. The dissimilar moisture contents of the diets probably had little influence on fish growth since the fish fed OMP and Abernathy at the 80% level were not significantly different in wet weight at the end of the experiment (Table 5). Other investigators have also found that dietary moisture content exerts little if any influence on fish growth provided that the available levels of dietary nutrients as determined by the type, level and quality of the components are similar (Poston 1974: Bromley 1980: Bromley and Smart 1981: Higgs et al. 1983: Markert et al. 1984: Higgs et al. 1985). It is noteworthy that the mean weights of the fish fed OMP at the 80 and 65% levels were significantly different not only at the end of stanza III, but also at the end of stanza II (Table 5). Therefore, adjustment of ration in this range (Table 4) would appear to influence growth although the effect of differences between groups in fish density cannot be discounted (Fagerlund et al. 1984).

The seasonal pattern for growth of all groups (Fig. 1) was characterized by three phases, namely early rapid growth until the fall equinox, slow or limited growth until shortly after the winter solstice and the resumption of rapid growth until the time of release. This pattern is typical of that observed in other years at this hatchery (J. Van Tine, pers. comm.; Markert et al. 1984). The condition factor (C.F.) decreased slowly at first and then more rapidly during smoltification (Fig. 2) indicating the fish were growing more rapidly in length than weight (Vanstone and Markert 1968). All groups showed the same trend regardless of dietary treatment. Moreover, all groups had very similar mean condition factors on day 310, except fish fed OMP at the 80% level. The mean condition factor of

these fish was significantly higher than noted for fish in the other groups (Table 7).

All groups exhibited a similar trend in their ability to convert food into flesh and to utilize dietary protein for growth or synthesis of body protein (Figs. 3, 4). Highest food and protein conversion were observed in stanza I and lowest in stanza II, the periods of rapid and slow growth respectively. Restriction of OMP to the 65% level did not significantly improve conversion efficiency in this experiment. This was probably because the actual rations (Table 4) ingested by the coho at the 80 and 65% levels were respectively above and below the level for optimum conversion efficiency.

The body composition of juvenile coho salmon at the end of the study (Table 8) was not significantly different with respect to moisture and ash content. However, significant differences did occur between groups for percentages of whole body lipid and protein. For example, the fish fed OMP at the 65% level had a significantly lower percentage of body lipid than noted for those fed OMP at the 80% level. This likely was a consequence of depressed lipid intake because of lowered ration and hence less storage of lipid in the body tissues. In addition, coho fed W.V.1 had significantly higher body protein content than those fed OMP at the 65% level. This probably stemmed from the higher ratio of protein to lipid in W.V.1 relative to OMP coupled with the higher food intake of the former group.

Irrespective of sampling time, the mean hematocrits of the groups exceeded 35% and at the time of release were above 40% (Table 7). Furthermore, before release no evidence of pathology was found in the histological structure of the liver, pancreas, kidney, alimentary tract, interrenal, gonad, thyroid or pituitary gland. However, bacterial kidney disease (BKD) was detected in 5 (W.V.2) to 7 (W.V.1) % of the fish fed the experimental dry diets and in 1% of the fish fed OMP (80%) and the Abernathy diet (Table 9). In moribund fish, the BKD incidence was very high for the W.V. groups. The total mortalities (Table 10) were highly variable in these five groups of juvenile coho, but the observed mortalities were generally low and less than 4% of the actual numbers of fish in each of the ponds. The one exception was the fish fed W.V.2, where overall mortality was 5.5%. The increased incidence of BKD in the W.V. groups undoubtedly caused higher mortality in these groups relative to the others.

No significant differences were found in the osmoregultory ability of coho at the time of release regardless of dietary treatment and plane of nutrition (Table 11). Most groups had plasma sodium levels near or below 170 meq/L and according to the findings of Clarke and Blackburn (1977) they should have adapted readily to seawater.

The estimated returns for 2, 3 and 4 - year - old coho are shown in Table 12. These include the returns to the commercial and sport fisheries and to the hatchery. The reliability of these numbers has been considered in some detail by Bilton et al. (1982) and Markert et al. (1984).

The total percent returns for the W.V. and production (OMP 65) fish were similar and they were either slightly or considerably below those for coho previously fed the Abernathy diet and OMP at the 80% level, respectively.

CONCLUDING REMARKS

The aforementioned findings are encouraging since this was the first of a series of feeding trials that have been conducted at the Quinsam River Hatchery to evaluate the potential of using dry feeds for coho smolt production. The results clearly show that dietary treatment had comparatively little effect on growth and food utilization. However, in regard to return rate it could be argued that diet did exert a major influence. Conversely, it could be debated that dietary treatment had little influence on return rate. For example, the variation in return rate between fish fed OMP at 80% and those fed OMP at the 65% level may have been due to their final size at the time of release because of the differences between groups in ration level. The findings of Bilton et al. (1982) support this thesis. In this regard it is noteworthy that coho fed W.V.1, W.V.2 and OMP at the 65% level were similar in final size and hence this could explain the similarity in return rate between these groups. Unfortunately BKD incidence was not measured in the coho fed OMP at the 65% level so the importance of this factor cannot be accurately assessed. If differences in composition between diets did influence return rates independent of an effect of fish size then the most probable cause for the reduced returns of coho fed W.V. diets stemmed from poor manufacturing practices in the private sector. For example, the problems encountered included the following: failure of the manufacturer on at least one occasion to properly stabilize the marine lipid, improper grinding of the ingredients, contamination of the food with other animal feeds, and improper particle sizes, e.g. pellet length much greater than diameter. The poor quality of commercially prepared W.V. diets likely caused the initiation of BKD since poor nutrition can compromise the immunocompetence of homeotherms and fish (Bell et al. 1984). The second feeding trial at the Quinsam River Hatchery where improved quality control was exercised during commercial feed manufacture resulted in marked increases in the total returns of fish fed W.V. diets. Other reasons for poor returns in experimental fish have been previously discussed by Markert et al. (1984).

Both this and the study by Markert et al. (1984) show that there is good potential for employing dry feeds manufactured under strict quality control for coho salmon culture. In the future it is anticipated that further improvements in the type, level and quality of the components used in the formulation of dry diets will result in equivalent or better performance of coho salmon than is presently possible with conventional moist foods. This will translate into more cost effective coho salmon smolt production than at present.

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Table 1. Composition of Oregon moist pellets (OMP-2).

Ingredients	g/kg diet as fed
Dry mix	
Fish meal	280-300
Cottonseed meal	170
Wheat germ meal	40
Dried whey product	50
Shrimp or crab meal	40
Corn distiller's dried solubles	20-40
Vitamin premix[a]	15
Wet mix	
Wet fish	300
Herring or soybean oil, antioxidant[b]	60
Choline chloride (liquid; 70% product)	5

[a] The vitamin supplement supplied the following levels of nutrients (mg/kg dry diet unless otherwise indicated): alpha tocopherylacetate 717 IU, menadione sodium bisulfite complex 25.7; pantothenic acid 151; B_6 25.2; riboflavin 75.5; niacin 269; folic acid 18.2; thiamine 33.7; biotin 0.85; B_{12} 85 µg; myo-inositol 378; vitamin C 1274.

[b] Stabilized with 0.3% BHA-BHT (1:1); soybean oil to be "fully refined"; herring oil to contain less than 5 ppm DDT or its analogs, less than 3% free fatty acids, and not to be alkaline reprocessed.

Table 1A. Composition of Abernathy diet.

Ingredients	g/kg diet as fed
Fish meal	
a) herring meal (C.P.[1] 67.5%)	480
b) anchovy meal (C.P.[1] 65%)	
Dried whey (maximum ash 10%)	100
Shrimp meal (C.P.[1] 38%)	50
Wheat middlings (C.P.[1] 15%)	0-150
Dried Brewers yeast (C.P.[1] 35%)	50
Dried blood flour (C.P.[1] 80%)	50
Vitamin premix[2]	15
Trace mineral mix	1
Choline chloride 70%	5
Stablized fish oil	50

[1] Crude protein

[2] The vitamin-trace mineral mix supplied the following levels of nutrients/kg dry diet: ascorbic acid 891 mg; biotin 0.59 mg; vitamin B_{12} 0.06 mg; alpha-tocopheryl 501 IU; folic acid 12.7 mg; inositol 264 mg; menadione 11.0 mg; niacin 220.1 mg; pantothenic acid 105.6 mg; pyridoxine-HCl 30.8 mg; riboflavin 52.8 mg; thiamine 42.9 mg; vitamin D_3 440 IU; vitamin A 6600 IU; Zn (as $ZnSO_4$) 74.8 mg; Mn (as $MnSO_4$) 74.8 mg; Fe (as $FeSO_4.7H_2O$) 9.9 mg; Cu (as $CuSO_4$) 1.5 mg; I (as KIO_3) 0.5 mg.

Table 2. Composition of test dry diet formulations. Four separate batches of West Van 1 (WV1) and West Van 2 (WV2) were prepared during the 310-day study. The ranges for each dietary component are shown.

Ingredients (g/kg dry diet)	Diet	
	WV-1	WV-2
Flame-dried herring meal (C.P.[1] = 72.9-76.0%)	301.3 - 353.4	114.4 - 141.1
Poultry-by-product meal (C.P. = 55.6-63.0%)	117.3 - 141.3	251.7 - 314.2
Feather meal (C.P. = 85.0-90.2%)	56.4 - 59.8	119.9 - 128.8
Blood flour (C.P. = 91.2-96.0%)	54.7 - 59.0	55.1 - 56.7
Soybean meal (C.P. = 50.4-52.2%)	133.1 - 145.0	133.1 - 150.1
Shrimp meal (C.P. = 35.9-48.0%)	58.1 - 67.1	58.1 - 69.4
Wheat middlings (C.P. = 16.8-17.5%)	36.3 - 127.5	84.2 - 97.2
Vitamin-mineral supplement[2]	40.0 - 43.0	40.0 - 43.0
Herring or salmon oil + antioxidant	55.2 - 59.6	36.8 - 41.1
Soybean lecithin	8.7 - 9.3	8.7 - 9.3
Permapell (lignin sulphonate-binder)	19.9 - 21.3	19.9 - 21.3
Kelp meal	10.0 - 10.0	10.0 - 10.9
DL-methionine + lysine HCl (lysine/methionine 3.2)	- -	13.9 - 15.6
Calcium phosphate dibasic	0 - 6.0	0 - 15.7

[1] Crude protein

[2] The vitamin-trace mineral supplement supplied the following levels of nutrients/kg of dry diet: vitamin A acetate 7037 IU; cholecalciferol 469 IU; dl alpha tocopherylacetate 748 IU; MSBC 11.7 mg; D-calcium pantothenate 84.4 mg; pyridoxine HCl 46.9 mg; riboflavin 56.3 mg; niacin 586 mg; folic acid 9.4 mg; thiamine mononitrate 46.9 mg; biotin 0.47 mg; cyanocobalamin 23.0 µg; inositol 422 mg; 60% choline chloride 938 mg; ascorbic acid (ethocel coated; Hoffmann-LaRoche) 1004 mg; NaCl 5300 mg; Mn (as $MnSO_4.H_2O$) 22.2 mg; I (as KI) 3.45 mg; Fe (as Fe_2O_3) 21.2 mg; Cu (as $CuSO_4$) 2.22 mg; Zn (as ZnO) 1.06 mg; Co (as $CoCl_2.6H_2O$) 0.21 mg. The vitamin supplement supplied 106 mg of ethoxyquin/kg diet.

[3] Marine oil was stabilized with 0.33% butylated hydroxyanisole-butylated hydroxy toluene (BHA-BHT) (1:1).

Table 3. Proximate composition of diets fed to juvenile coho salmon over a 310-day period. Means ± 1 SEM (measured values only) are shown. Refer to Tables 1, 1A and 2 for additional information.

Proximate analysis (% of dry matter)	Diet			
	WV-1	WV-2	Abernathy	OMP
Protein (% N x 6.25)	49.3 ± 2.0	53.1 ± 0.9	47.2 ± 1.4	50.5 ± 1.1
Crude lipid (Bligh-Dyer)	13.3 ± 0.5	12.7 ± 0.6	11.6 ± 1.0	14.5 ± 0.8
Crude fiber[1]	5.4	5.6	3.1	3.6
Nitrogen-free extract (NFE)	21.7	18.5	26.4	21.6
Ash	10.3 ± 0.2	10.1 ± 0.2	11.7 ± 0.3	9.8 ± 0.4
Moisture (as fed)	8.6 ± 0.6	8.0 ± 0.3	5.5 ± 0.5	26.4 ± 1.0
Metabolizable energy (kcal/g)[2]	3.48	3.54	3.33	3.62
Digestible protein (mg/dig kcal)[3]	127.5	135	127.5	125.5

[1] Crude fiber content of the diets estimated (NRC, 1981). Subsequently, NFE values were calculated.

[2] Brett and Groves (1979) coefficients used for estimating caloric value of the diets, i.e., 4.2 kcal/g crude protein; 8.0 kcal/g crude lipid and 1.6 kcal/g carbo .

[3] Calculated assuming protein 90% digestible.

Table 4. Estimated rations (dry food (g)x 100 ÷ wet body weight (g)) consumed by juvenile coho salmon fed experimental dry diets, Abernathy or OMP. Prescribed rations were either 80% (WV1, WV2, OMP 80) or 65% (OMP 65) of those recommended in the Oregon moist pellet feeding chart on gross energy basis.

	Diet				
Day	WV1	WV2	Abernathy	OMP (80%)[1]	OMP (65%)
0	2.65	2.98	2.82	3.22	-
28	2.20	1.94	1.76	2.36	-
56	1.44	1.53	1.63	2.01	-
84	1.30	1.20	1.12	1.52	1.29
112	1.19	1.14	1.12	1.27	1.19
143	1.14	1.05	1.15	1.19	1.27
169	0.72	0.75	0.63	0.86	0.68
196	0.79	0.64	0.63	0.82	0.66
225	0.60	0.61	0.54	0.75	0.63
252	0.67	0.62	0.64	0.73	0.66
280	0.69	0.76	0.60	0.84	0.68
310	0.53	0.51	0.53	0.70	0.54

[1] Estimates are consistently higher than the prescribed ration because the actual number of fish was less than the number assumed to be in this pond.

Table 5. Wet weights (geometric means with 2SE on either side of mean shown in parentheses) and growth rates of juvenile coho salmon fed experimental dry diets, Abernathy and OMP; the latter at two ration levels. Refer to Tables 1, 1A and 2 for additional information.

Parameter	Stanza	Day	Diet				
			WV1	WV2	Abernathy	OMP (80%)	OMP (65%)
Wet weight[1] (g)		0	3.57[c]	3.16[a,b]	2.91[a]	3.25[b,c]	-
			(3.33- 3.82)	(2.95- 3.38)	(2.72- 3.11)	(3.04- 3.48)	-
	1	84	12.96[c]	10.59[b]	9.13[a]	10.56[b]	9.82[a,b]
			(12.25-13.71)	(10.10-11.20)	(8.64- 9.66)	(9.98-11.17)	(9.29-10.39)
	2	225	15.55[a,b]	14.56[a]	15.66[a,b]	16.33[b]	14.89[a]
			(14.74-16.41)	(13.80-15.36)	(14.84-16.52)	(15.48-17.24)	(14.11-15.72)
	3	310	21.97[b]	20.47[a]	22.29[b,c]	23.16[c]	18.62[a]
			(20.94-23.06)	(19.51-21.49)	(21.24-23.39)	(22.07-24.30)	(17.75-19.54)
Growth rate[2]	1		1.58[c]	1.52[b,c]	1.33[b]	1.47[b,c]	-
(% wet wt/day)			±0.05	±0.05	±0.05	±0.05	-
	2		0.09[a]	0.12[a,b]	0.27[c]	0.22[b,c]	0.25[b,c]
			±0.03	±0.03	±0.03	±0.05	±0.03
	3		0.49[a]	0.33[a]	0.52[a]	0.30[a]	0.46[a]
			±0.06	±0.06	±0.06	±0.06	±0.06

[1] One-way Analysis of variance (ANOVA) for each time indicated $P < 0.001$ for day 0, 84 and 310, and $P < 0.05$ for day 225. Diet groups with the same superscript were not significantly different (Newman Keuls test with $P = 0.05$).

[2] Analysis of covariance with equality of slope test across diets for $\log_e$ wet weights indicated $P < 0.01$ for stanza 1 and $P < 0.001$ for stanza 2 and $P > 0.05$ for stanza 3. Diet groups with the same superscript form a homogeneous subset (Scheffe's multiple range test with $P = 0.05$).

Table 6. Dry weights (geometric means with 2SE on either side of mean shown in parentheses) and growth rates (mean ± 2SEM) for groups of juvenile coho salmon fed experimental dry diets, Abernathy or OMP at two ration levels. Refer to Tables 1, 1A and 2 for additional information.

Parameter	Stanza	Day	Diet				
			WV1	WV2	Abernathy	OMP (80%)	OMP (65%)
Dry weight[1] (g)	1	0	0.84[c]	0.71[a,b]	0.65[a]	0.76[b]	-
			(0.78-0.89)	(0.67-0.76)	(0.61-0.70)	(0.71-0.81)	-
	1	84	3.50[c]	2.79[b]	2.30[a]	2.80[b]	2.59[a,b]
			(3.31-3.70)	(2.64-2.95)	(2.17-2.95)	(2.65-2.96)	(2.52-2.67)
	2	225	4.09[b,c]	3.70[a]	4.03[b,c]	4.29[c]	3.83[a]
			(3.88-4.32)	(3.50-3.90)	(3.82-4.25)	(4.07-4.52)	(3.64-4.04)
	3	309	5.05[b]	4.70[a]	5.10[b]	5.61[c]	4.68[a]
			(4.81-5.30)	(4.48-4.93)	(4.86-5.35)	(5.34-5.88)	(4.46-4.91)
Growth rate[2] (% dry wt/day)	1		1.76[b]	1.72[b]	1.48[a]	1.62[a,b]	-
			±0.05	±0.05	±0.05	±0.05	-
	2		0.08[a]	0.11[a,b]	0.30[c]	0.19[a,b,c]	0.24[b,c]
			±0.03	±0.03	±0.03	±0.03	±0.03
	3		0.29[a]	0.17[a]	0.36[a]	0.11[a]	0.28[a]
			±0.06	±0.06	±0.06	±0.06	±0.06

[1] One-way ANOVA for each time indicated $P < 0.001$ for day 0, 84 and 310, and $P < 0.01$ for day 225. Diet groups with the same superscript were not significantly different (Newman Keuls test with $P = 0.05$).

[2] Analysis of covariance with equality of slope test across diets for $\log_e$ dry weights indicated $P < 0.001$ for stanza 1 and 2 and $P > 0.05$ for stanza 3. Diet groups with the same superscript form a homogeneous subset (Scheffe's multiple range test with $P = 0.05$).

Table 7. Condition factors and hematocrits for groups of juvenile coho salmon d x r mental dry diets Abernathy or OMP at two ration levels. Means and two standard errors of mean are shown. Also, numbers of fish examined for hematocrit are indicated in parentheses. Refer to Tables 1, 1A and 2 for additional information.

Parameter	Stanza	Day	Diet					2 SEM
			WV1	WV2	Abernathy	OMP (80%)	OMP (65%)	
Condition[1] factor	1	0	7.45[a]	7.46[a]	7.42[a]	7.45[a]	-	0.04
	1	84	6.81[a]	6.83[a]	6.81[a]	6.95[b]	6.87[a]	0.03
	2	225	5.97[a]	6.02[a]	6.26[b]	6.38[c]	6.22[b]	0.03
	3	310	5.09[a]	5.09[a]	5.14[a]	5.30[b]	5.17[a]	0.03
Hematocrit (%)								
	2	94	46.13(15)	43.40(15)	38.86(15)	35.53(15)		
			1.72	1.49	0.86	2.29		
	2	146	41.53(15)	41.13(15)	39.20(15)	41.40(15)		
			1.39	1.45	1.38	1.64		
	2	203	43.86(15)	44.93(15)	44.33(15)	44.36(30)		
			1.95	3.09	1.50	1.15		
	3	239	40.26(15)	36.06(15)	38.13(15)	37.80(15)		
			1.83	1.57	2.12	1.25		
	3	308	46.13(15)	41.13(15)	44.86(15)	44.86(15)		
			0.99	2.19	1.91	2.51		

[1] Calculated as wet weight (g) x 1000 ÷ fork length (cm) $^{3.25}$. One-way ANOVA for each time indicated $P > 0.05$ for day 0, $P < 0.01$ for day 84, and $P < 0.001$ for day 225 and 310. Diet groups with the same superscript were not significantly different (Newman Keuls test with $P = 0.05$).

Table 8. Terminal body proximate composition of junveile coho salmon fed experimental dry diets, Abernathy or OMP at two ration levels for 310 days.

Parameter	Diet WV1	WV2	Abernathy	OMP (80%)	OMP (65%)
Moisture (%)	77.03[a]	77.05[a]	77.12[a]	76.44[a]	77.11[a]
	0.68	0.83	0.79	0.75	0.88
Ash (%)	2.53[a]	2.62[a]	2.67[a]	2.37[a]	2.39[a]
	0.27	0.32	0.35	0.55	0.42
Lipid (%)	3.50[a,b]	3.24[a,b]	3.25[a,b]	3.82[b]	3.12[a]
	0.73	0.49	0.63	0.32	0.38
Protein (%)	17.12[a]	16.79[a,b]	16.45[a,b]	16.18[a,b]	15.96[b]
	0.87	0.90	0.63	0.52	0.33

Diet groups with the same superscript were not significantly different (Newman Keuls test with P = 0.05).

Table 9. Fish health and histological assessments of juvenile coho salmon just before release from Quinsam hatchery. Ten representative fish from each diet treatment were examined histologically. Refer to Tables 1, 1A and 2 for additional information.

	Diet				
	WV1	WV2	Abernathy	OMP (80%)	OMP (65%)
Disease evaluation					
Furunculosis incidence	-	-	-	-	-
Bacterial kidney disease[1] incidence	7/100	5/100	1/100	1/100	-
Histological assessment					
Liver[2]	N(HL)	N(HL)	N(HL)	N(HL)	N(HL)
Kidney	N	N	N	N	N
Pancreas	N	N	N	N	N
Alimentary tract	N	N	N	N	N
Interrenal	N	N	N	N	N
Gonad[4]	N	N	N	N	N
Thyroid[5]	N	N	N	N	N
Pituitary[6]	N	N	N	N	N

[1] Bacterial kidney disease incidence in moribund fish removed from groups fed WV1, WV2, Abernathy, and OMP (80%) was respectively 14/15, 11/15, 1/12, and 0/7.

[2] Groups fed WV1, WV2, Abernathy, OMP (80%) and OMP (65%) had high hepatic and omentum lipid deposition (HL). The liver and omentum in wild smolts contained a low level of lipid.

[3] Normal structure.

[4] In all groups, ova were in the late perinucleolar stage and measured 180-270 μ.

[5] Histological criteria indicated high thyroid activity in all groups. Thryoid follicle epithelial cell heights in most fish examined ranged between 4.5 and 6.5 μ. Readsorption vacuoles were common and a few mitotic figures were noted in each follicle.

[6] In all groups pituitary cytology was typical of healthy smolts. Large, well granulated somatotrops were the dominant cell type.

Table 10. Observed mortality and unaccountable loss of juvenile coho salmon for each growth stanza and over the 310-day experimental period. Mortality is expressed relative to the estimated number of fish at the beginning of each stanza (within) or to the estimated initial number of fish on day 0 (overall). Refer to Tables 1, 1A and 2 and Figure 1 for additional information.

			Diet				
Stanza	Day	Fish loss (%)	WV1	WV2	Abernathy	OMP (80%)	OMP (65%)
1	0-84	observed	0.85	1.03	0.75	0.50	1.02
		unaccountable	9.31	1.74	0.24	2.13	0.25
2	85-225	observed	0.38	0.39	0.35	0.38	0.55
		unaccountable	9.36	4.56	0.24	1.93	0.23
3	226-309	observed	2.89	4.18	1.61	0.29	0.69
		unaccountable	0	0	0	0	0.09
1-3	0-310	observed	3.82	5.46	2.68	1.17	2.23
		unaccountable	18.34	5.41	0.42	3.97	0.56

Table 11. Plasma sodium titres (X ± 2SEM) in juvenile coho 24 hr after transfer to 10°C seawater (salinity 29-30‰). Osmoregulatory challenge test was conducted on May 8, 1978. Numbers of fish sampled are indicated in brackets.

Diet	Mortality 24 hr after SW transfer	Wet Weight (g)	Plasma sodium (meq/l)[1]
WV1	0	19.3 ± 1.5	165.2 ± 7.2 (12)
WV2	0	20.5 ± 1.8	160.1 ± 7.0 (12)
Abernathy	0	18.9 ± 1.2	160.6 ± 5.4 (12)
OMP (80%)	0	23.0 ± 1.8	180.7 ± 7.8 (11)
OMP (65%)	0	19.9 ± 1.7	171.9 ± 19.6 (12)

[1] ANOVA indicated no significant differences between groups ($P > 0.05$).

Table 12 - Estimated returns of 2, 3 and 4 year-old cultured 1977 brood Quinsam hatchery coho. Estimated percent returns are shown for the commercial and recreational fisheries, hatchery and overall. Cultured fish received experimental dry diets Abernathy or OMP during freshwater residency.

		1976 Brood				
Diet		WV1	WV2	Abernathy	OMP 80	OMP 65
Tag code		02-1917	02-1918	02-1920	02-1919	02-1921
No. of fish released-total		43,387	46,192	53,294	48,232	346,277
-tagged		23,404	21,389	23,071	23,785	48,319
Release date		May 7/78	May 7/78	May 7/78	May 7/78	May 1-4/78
Release weight						
fish/lb		20.0	21.1	20.0	18.3	23.0*
mean (g)		22.7	21.5	22.8	24.8	19.7*
Returns (estimated)						
Canadian	(1978)	32	64	61	77	81
	(1979)	674	675	937	1378	1665
	(1980)	3	4	0	5	0
United States	(1978)	2	0	0	0	0
	(1979)	16	0	10	15	19
	(1980)	0	0	0	6	0
Hatchery	(1978)	358	346	324	894	436
	(1979)	206	164	244	370	426
	(1980)	0	0	0	0	0
% to hatchery		2.41	2.38	2.96	5.31	1.78
Total		1291	1253	1576	2759	2627
% returns		5.52	5.86	6.83	11.60	5.44

* The mean weight of the fish in the one production pond monitored was 21.4 g

Fig. 1 - Patterns for water temperature, daylength and growth of juvenile coho salmon during the study period. Three periods of experimental growth were observed for all groups. Fish were fed experimental dry diets (WV1, WV2), Abernathy or Oregon Moist Pellets (OMP) at a ration level of 80% of the OMP feeding schedule on a gross caloric basis. WV1 and WV2 were prepared in the laboratory during the first portion of the study. Thereafter the diets were manufactured commercially.

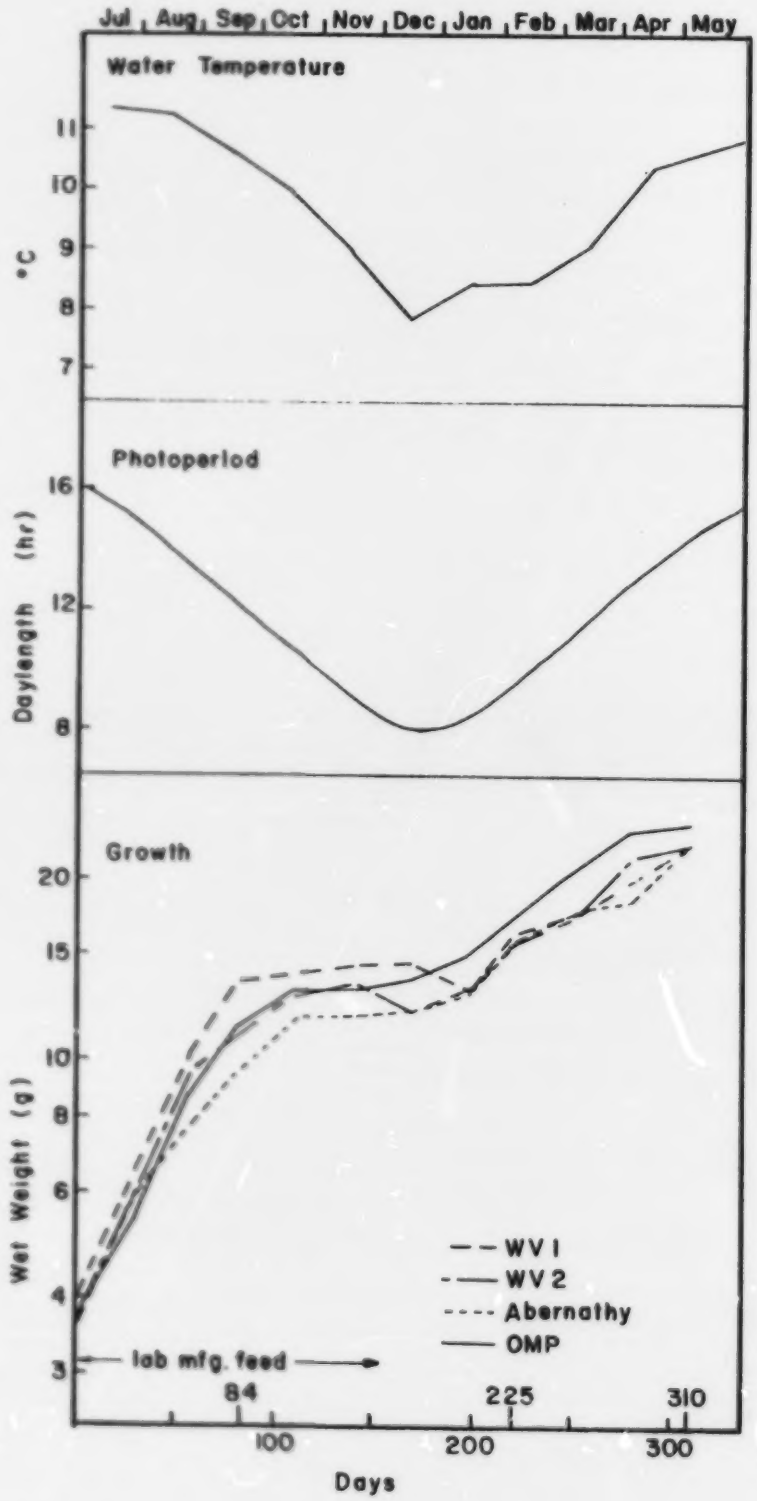
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Water Temperature
°C
11
10
9
8
7
Photoperiod
Daylength (hr)
16
12
8
Growth
Wet Weight (g)
20
15
10
8
6
4
3
WV 1
WV 2
Abernathy
OMP
lab mfg. feed
84
225
310
100
200
300
Days

Fig. 1

Fig. 2 - Monthly changes in condition factor of juvenile coho salmon fed test day (WV1, WV2), Abernathy or OMP at two ration levels. The duration of each of the three growth stanzas (1, 2, and 3) is indicated.

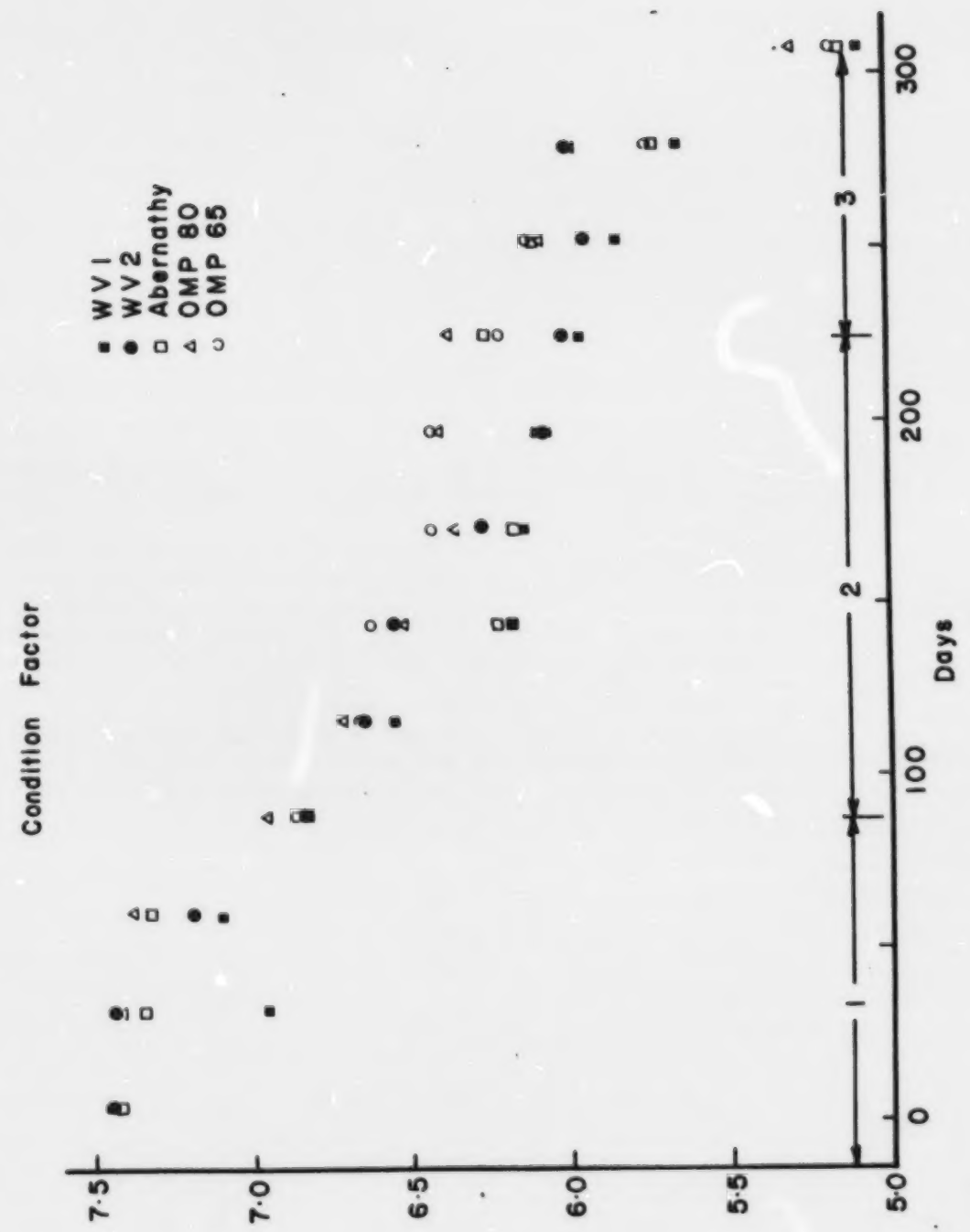
WV 1
WV 2
Abernathy
OMP 80
OMP 65
Condition Factor
7·5
7·0
6·5
6·0
5·5
5·0
0
1
2
3
100
200
300
Days

Fig. 2

Fig. 3 - Food conversion and protein efficiency ratios for groups of juvenile coho fed WV1, WV2, Abernathy, or OMP at two ration levels.

Food conversion: Two-way ANOVA with one observation per cell and a three factor ANOVA with diet crossed with time nested in stanza and one observation per cell indicated no significant differences in food conversion between diet groups within or between stanzas ($P > 0.05$). Food conversion was significantly depressed in stanza II relative to stanza I (Newman-Keuls test with $P = 0.05$).

Protein efficiency ratio: ANOVA (designs identical to those for food conversion) and Newman-Keuls test with $P = 0.05$ indicated identical findings to those mentioned above for food conversion.

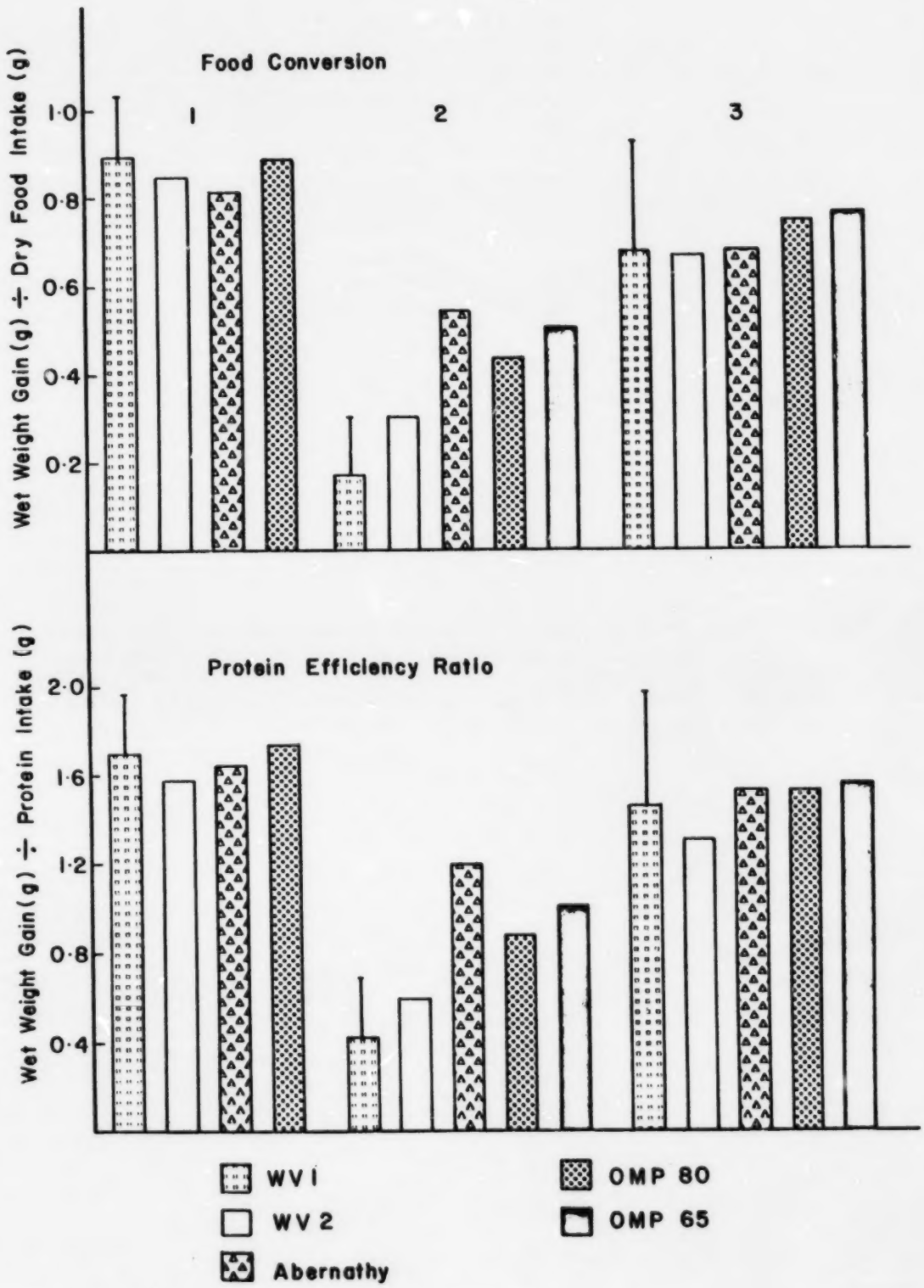
Food Conversion
1
2
3
Wet Weight Gain (g) ÷ Dry Food Intake (g)
1·0
0·8
0·6
0·4
0·2
Protein Efficiency Ratio
Wet Weight Gain (g) ÷ Protein Intake (g)
2·0
1·6
1·2
0·8
0·4
WV 1
WV 2
Abernathy
OMP 80
OMP 65

Fig. 3

Fig. 4 - Gross food conversion efficiency, protein efficiency ratio (dry rather than wet weight gain ÷ protein intake) and protein utilization for groups of coho fed WV1, WV2 Abernathy or OMP at two ration levels. Identical trends to those reported in Fig. 3 were found.

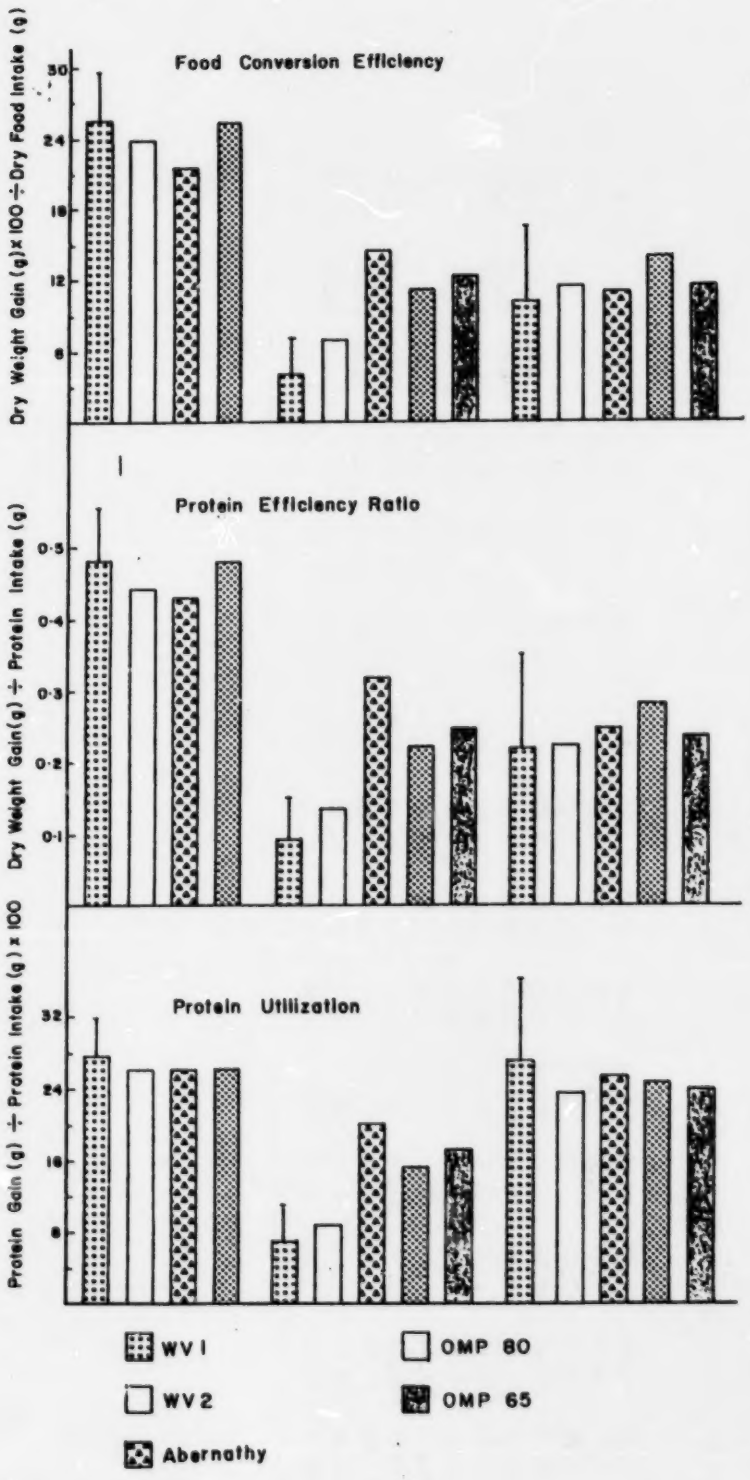
Food Conversion Efficiency
Dry Weight Gain (g) x 100 ÷ Dry Food Intake (g)
30
24
18
12
6
Protein Efficiency Ratio
Dry Weight Gain(g) ÷ Protein Intake (g)
0·5
0·4
0·3
0·2
0·1
Protein Utilization
Protein Gain (g) ÷ Protein Intake (g) x 100
32
24
16
8
WV I
WV 2
Abernathy
OMP 80
OMP 65

Fig. 4

APPENDIX

TABLE 1. Mean lengths (L), weights (Wt) and condition factors (CF) of th groups during the study.

Day	WV1			WV2			Abernathy			OMP (80%)			OMP (65%)		
	L	Wt	CF	L	Wt	CF	L	Wt	CF	L	Wt	CF	L	Wt	CF
0	6.73	3.83	7.45	6.48	3.44	7.46	6.33	3.15	7.42	6.56	3.56	7.45	-	-	-
28	7.95	6.20	6.95	7.50	5.53	7.44	7.73	5.89	7.34	7.39	5.24	7.42	-	-	-
56	9.26	10.14	7.09	9.08	9.57	7.19	8.40	7.72	7.32	8.74	8.74	7.37	-	-	-
84	10.25	13.43	6.81	9.66	11.34	6.83	9.22	9.57	6.81	9.60	11.34	6.95	9.39	10.21	6.87
112	10.41	13.86	6.56	10.14	12.86	6.65	9.89	11.64	6.64	10.20	13.17	6.72	9.83	11.65	6.66
143	10.80	14.45	6.19	10.54	13.43	6.22	10.11	11.72	6.21	10.30	13.11	6.53	9.98	12.05	6.63
169	10.81	14.53	6.15	10.13	12.05	6.27	10.21	12.06	6.17	10.52	13.71	6.36	10.16	12.57	6.43
196	10.52	13.44	6.07	10.55	13.46	6.08	10.50	13.08	6.10	10.70	14.83	6.42	10.42	13.72	6.44
225	11.29	16.11	5.97	11.06	15.42	6.02	11.16	16.38	6.26	11.27	17.47	6.38	11.02	15.73	6.22
253	11.60	17.36	5.85	11.63	17.82	5.95	11.44	17.23	6.10	12.12	20.98	6.12	11.30	17.02	6.13
281	12.26	19.95	5.66	11.79	18.41	5.75	12.40	21.52	5.82	12.74	24.03	6.01	12.09	19.50	5.75
310	13.19	22.70	5.09	12.94	21.51	5.09	13.20	22.92	5.14	13.39	24.89	5.30	12.87	21.41	5.17